W+jet production at CDF

Andrea Messina

MICHIGAN STATE UNIVERSITY

INFN Roma
Istituto Nazionale di Fisica Nucleare

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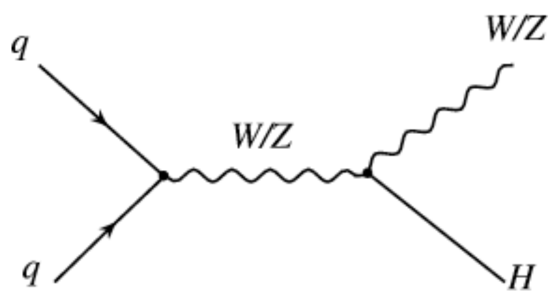
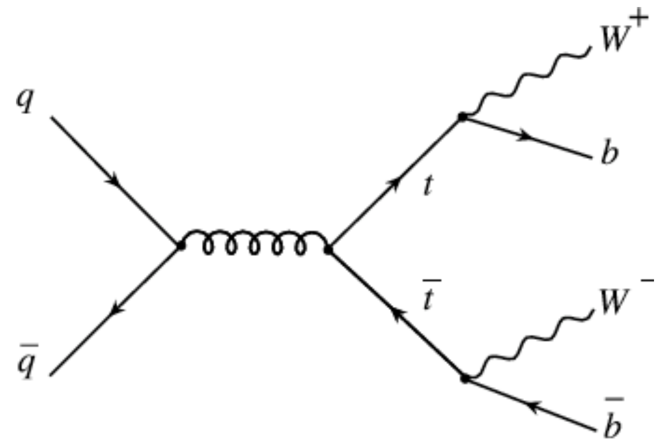
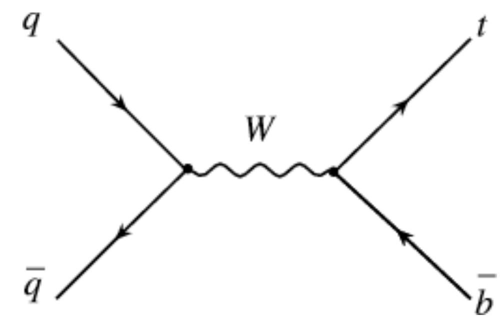
OUTLINE

- Why boson + jet
- W + jet measurement
  - ✓ observable definition
  - ✓ background estimate
  - ✓ σ(W+jet) results
  - ✓ systematic errors
- conclusions & plans

Motivation I







- ✓ Boson + jet is the signature for a number of high p_T physics processes:
  - Top pair & single top production
  - Higgs boson searches
  - Searches for super-symmetric particles
- ✓ All these signals are overwhelmed by a large QCD production of boson + jet
- ✓ It is crucial to have a good understanding of such a process

Motivation II

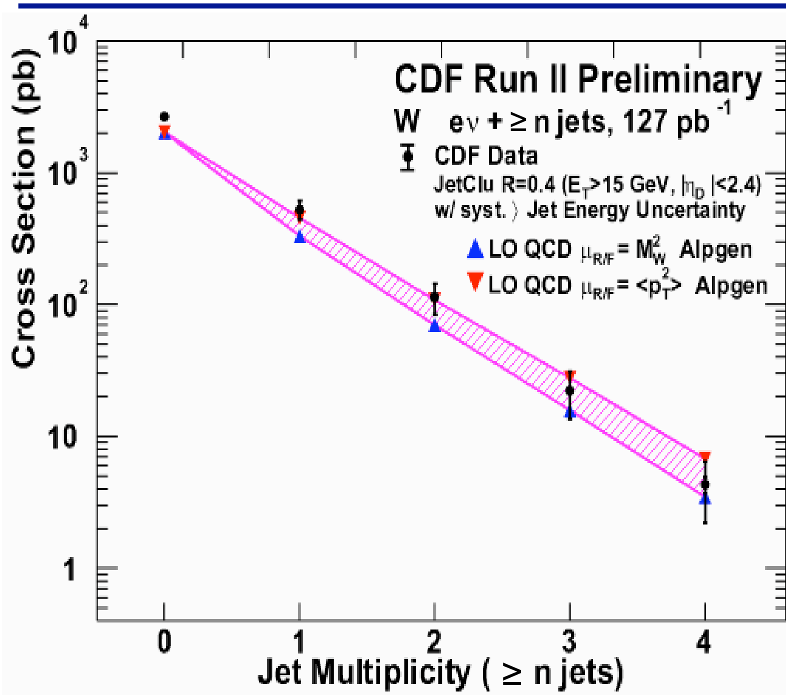
Testing ground for pQCD in multijet environment

✓ The presence of a boson:
- Ensures high Q^2 - pQCD
- Large BR into leptons - easy to detect experimentally

✓ Study the underlying event in an alternative topology than inclusive jets

✓ Key sample to test LO and NLO calculations
- Pythia, Herwig: shower, ME(W & W + 1parton)
- AlpGen, Sherpa, MadGraph: W + multi-parton ME & matching algorithm (ckkw/MLM) with shower
- CompHep, Gr@PPA: W + multi-parton ME with shower
- MCFM: NLO ME W + 1 or 2 partons
- MC@NLO: W+X (NLO ME + herwig shower)

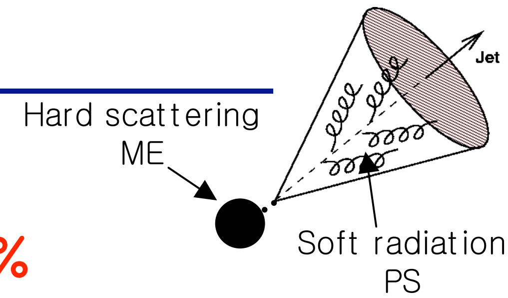
σ(W+≥ N jets) vs LO QCD



LO calculation:

rate uncertainty » 50%

shape » 20%

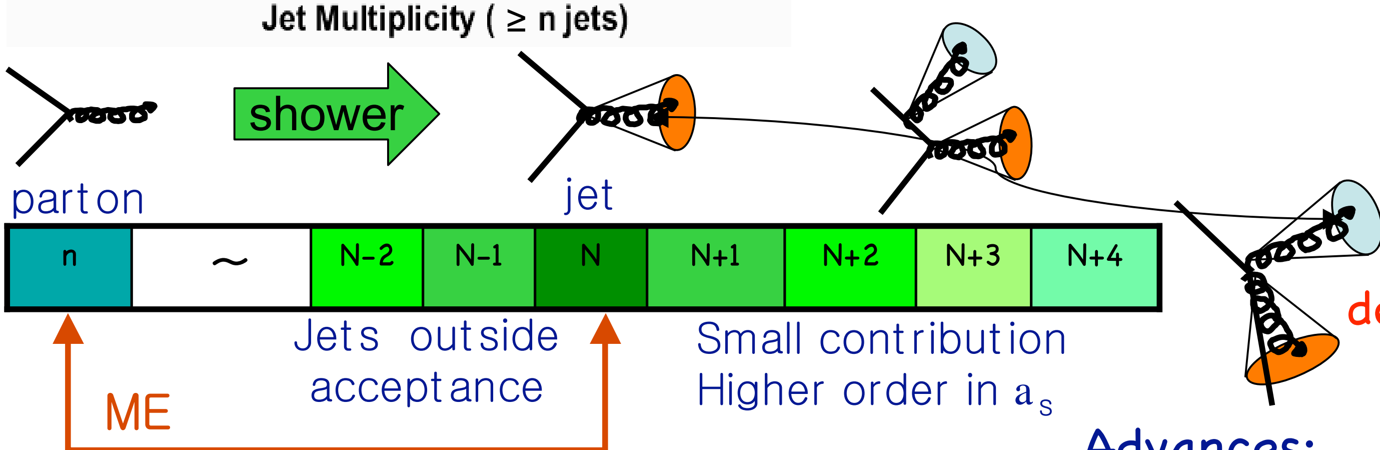


Naïve:

(W+n parton ME)+(PS) » W + ≥ Njet

(W+(n+1) parton ME)+(PS) » W + ≥ N+1jet

………



2 topologies » O(a)
Same jet multiplicity

double counting

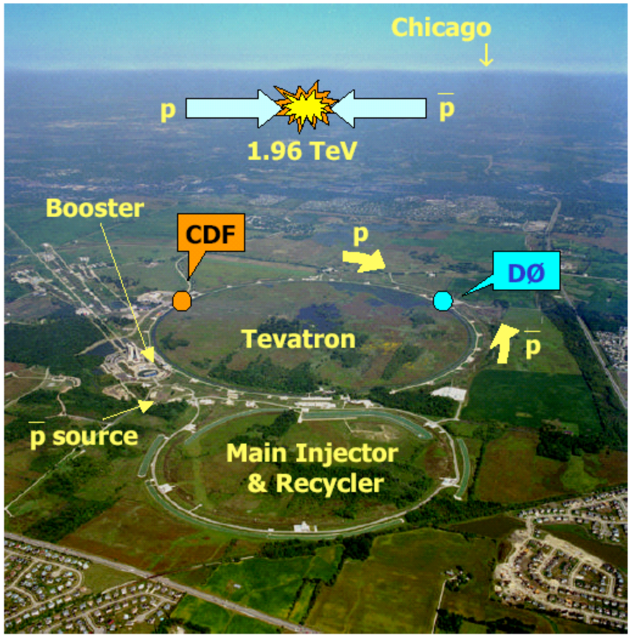
dep. on parton-level cuts

Advances:

ME-PS matching - CKKW & MLM

NLO predictions

Experiment apparatus



- p-pbar collisions, 36 bunches-396 ns
  $\sqrt{s}$=1.96 TeV (RunI 1.8)
- record peak Lumuminosity
  2×10^{32} [$cm^{-2}s^{-1}$]
- ≈ 1.8 fb^{-1} delivered
- ≈ 25 pb^{-1}/week

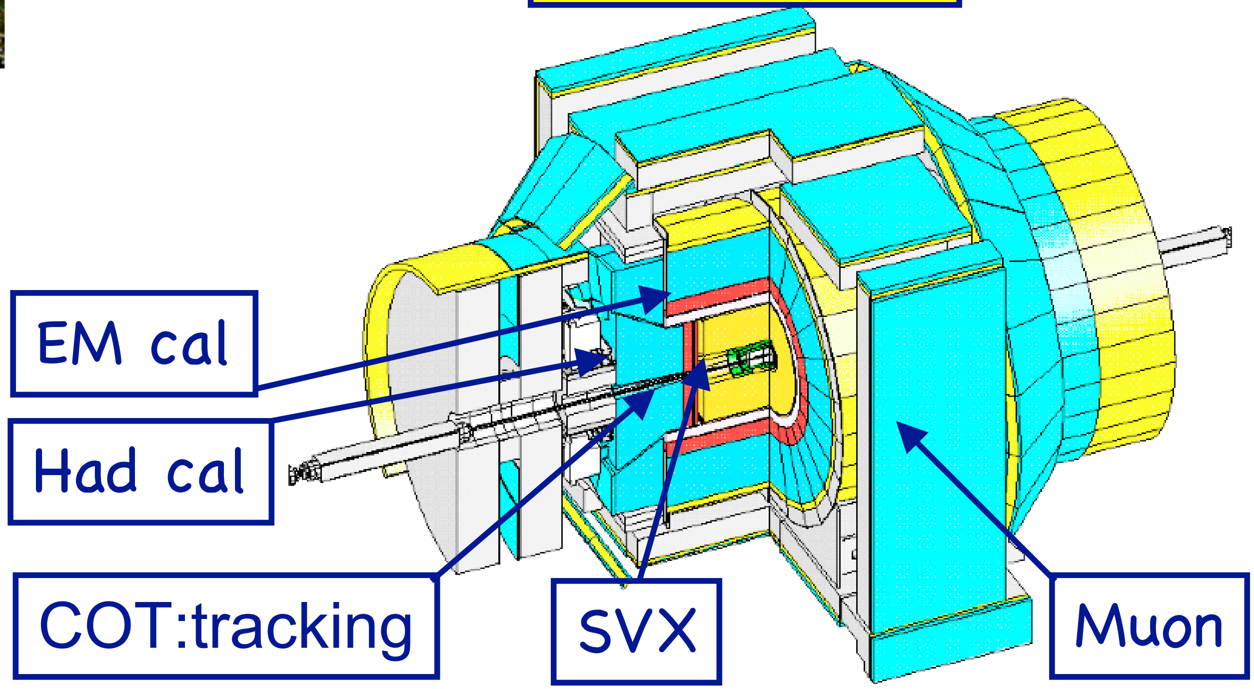
➢Silicon detector (SVX):
  top event b-tag: ~55%

➢COT: drift chamber
  Coverage: $|\eta|<1$
  $\sigma_{P_t} / P_T \sim 0.15\%\ P_T$

➢Calorimeters:
  Coverage: $|\eta|<3.6$
  EM: $\sigma_E / E \sim 14\% /\sqrt{E}$
  HAD: $\sigma_E / E \sim 80\% /\sqrt{E}$

➢Muon:
  muon ID up-to $|\eta|$=1.5

CDF detector



W + jet measurement definition

- ✓ σ(W->eν + jet) vs jet $E_{T,}$ jet-jet DR and invariant mass.
- ✓ Be as much as possible independent of theoretical models.

$$\frac{\delta\sigma\left[\begin{array}{l} P_T^e > 20, M_T > 20 \\ P_T^\upsilon > 30, \eta^e < 1.1 \end{array}\right]}{\delta E_T^j}$$

Restrict W xsec to the measurable phase space

Jets corrected hadron level
JETCLU 0.4
E_T^{corr}>15 GeV; |h|<2.0

- ✓ This is not an EWK measurement: the W is a clean signal for high Q^2 events within which we can examine jet kinematics.

W + jet measurement definition

High P_T electron trigger 320pb^{-1} → Identify W, reconstruct jets

- ✓ In each bin of the jet E_T distribution compute:

$$\sigma = \frac{N^{cand} - N^{bkgd}}{A \bullet \varepsilon_{ID} \bullet L}$$

- ✓ Background: QCD, W->$\tau\nu$, Z->ee, WW, top, extra interactions
- ✓ Acceptance largely independent of theoretical model
- ✓ Never rely on MC for rates, for shapes assign a model dependence error by comparing to data or largely vary MC parameters.

Acceptance and Efficiency

- ✓ Define xsec phase space as the W detector acceptance
  - Events migrate across acceptance boundary: convolution of local shape and resolution

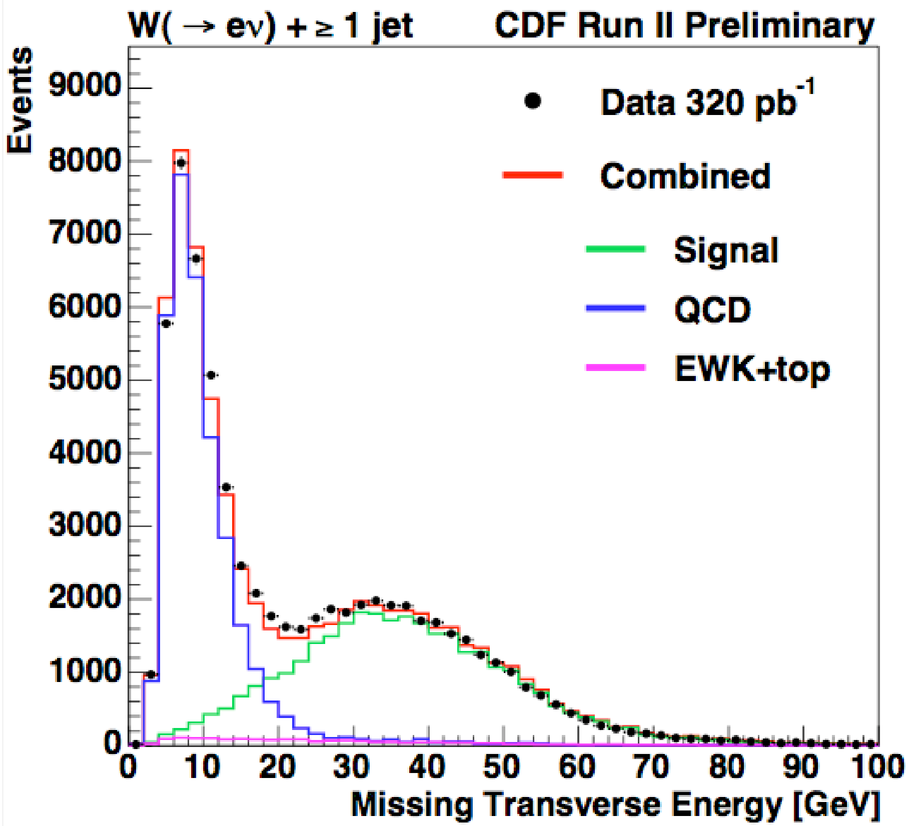
- ✓ Use MC for acceptance and electron ID efficiency
  - Systematic on ID efficiency comparing Z MC and data
  - Systematic on acceptance from different MC models

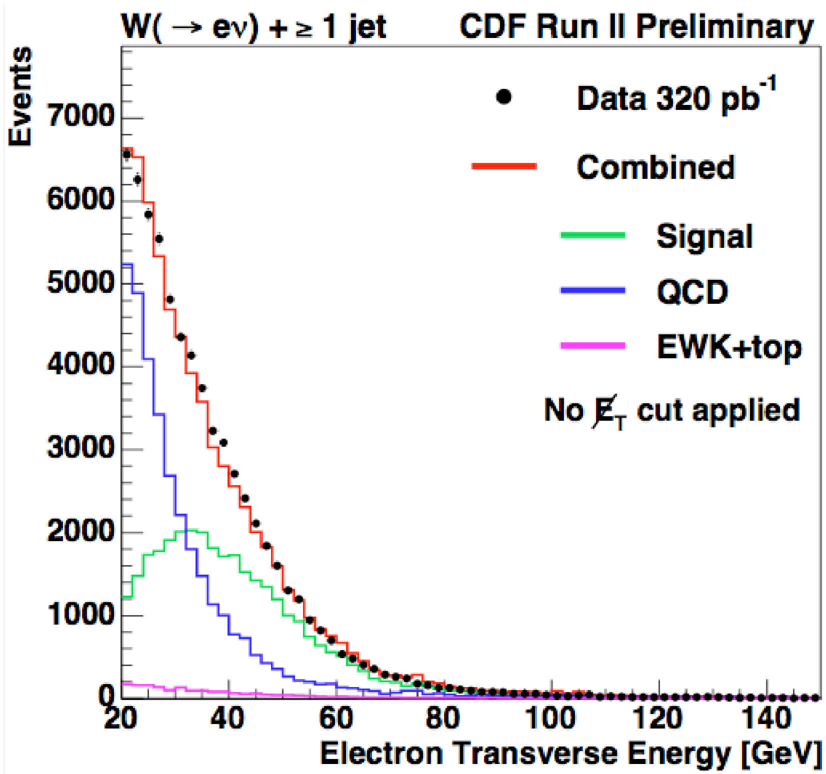
$$A \bullet \varepsilon_{ID} \approx 0.6 \pm 0.03$$

largely flat as function of jet kin

Background

- QCD from fake electron (antielectron)
- Use MC for EWK & top
- Relative normalization from ME_T fit to data
- Excellent agreement with data in other kinematic variables



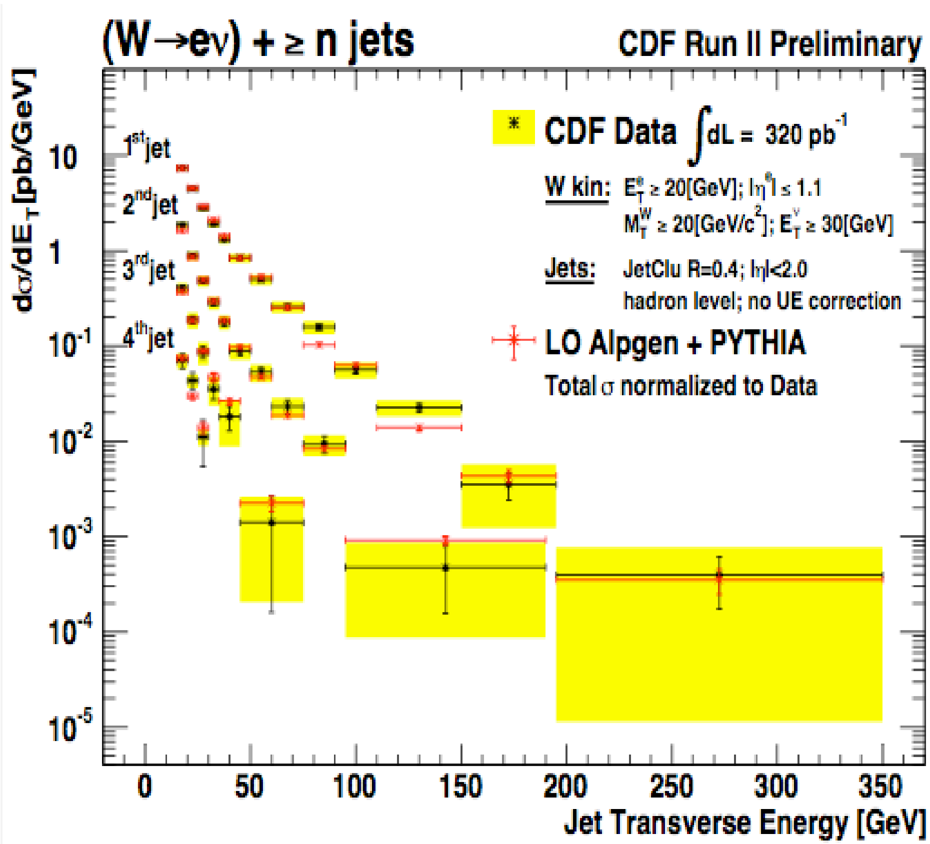


Systematics:

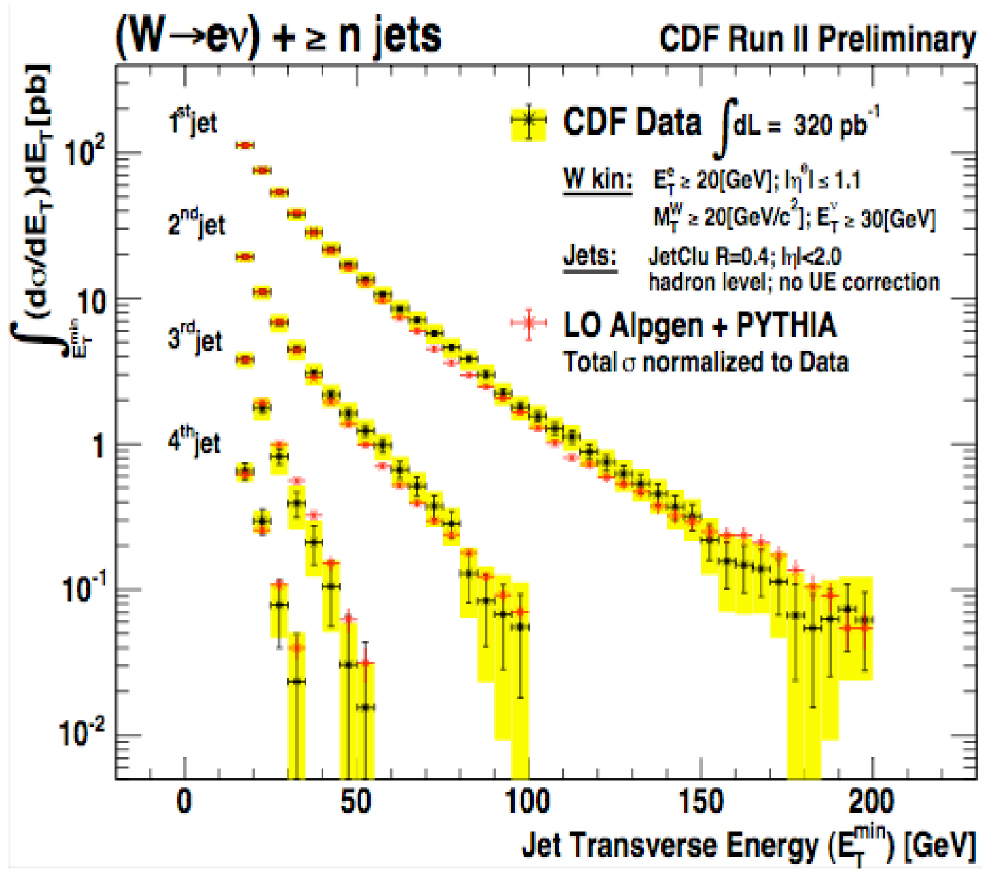
- antielectron statistic
- antielectron model (5-20%)
- Top cross section (10-20%)
- MC model (5%)

CDF W+jet cross section measurement

Differential xsec wrt jet E_T in each of the 4 W+ n jet inclusive samples



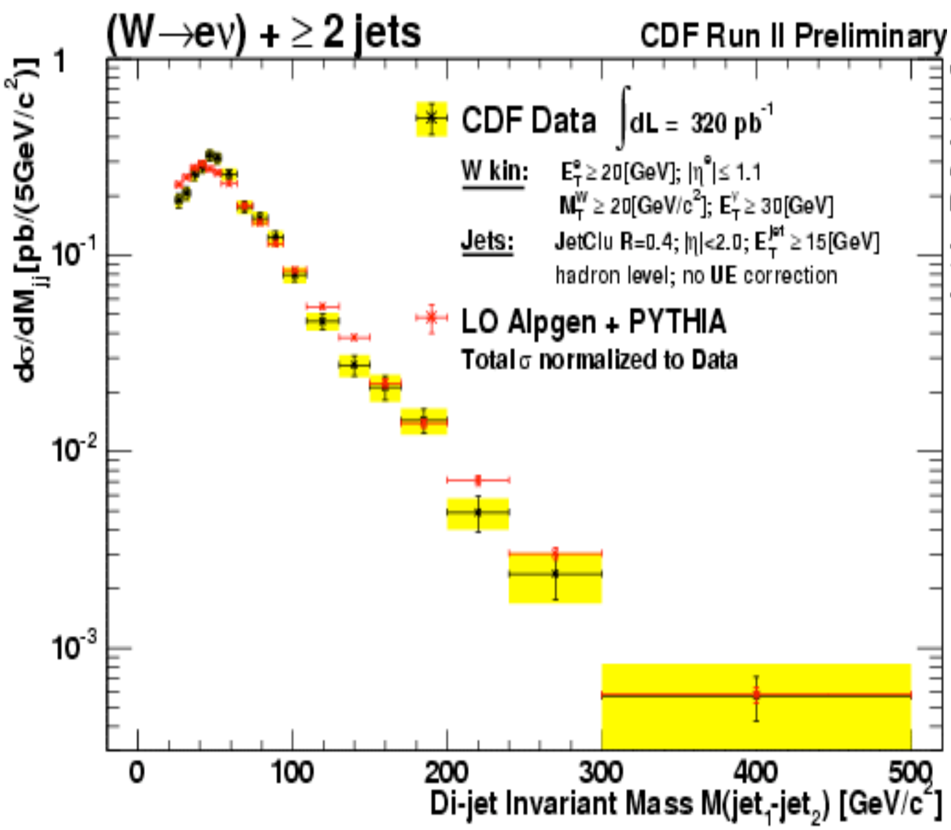
Integrated xsec wrt jet E_T in each of the 4 W+ n jet inclusive samples



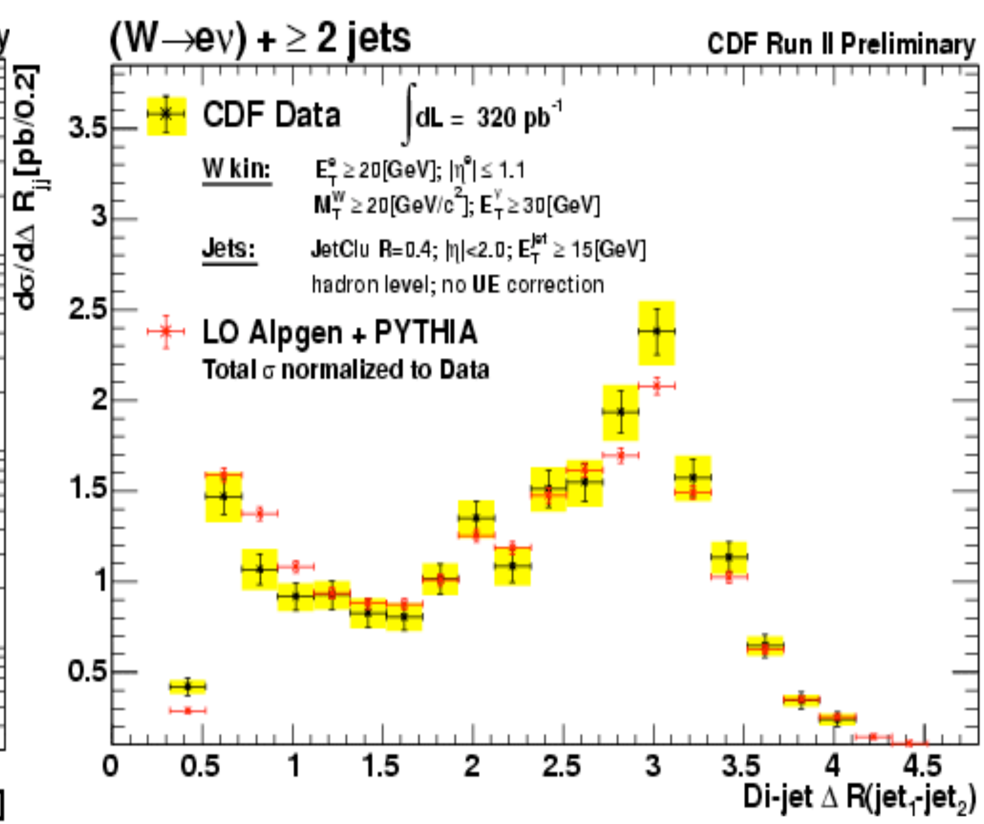
MC have been normalized to inclusive data cross section in each jet sample!

CDF W+jet cross section measurement

Differential xsec wrt di-jet invariant mass in the W+ 2 jet inclusive samples

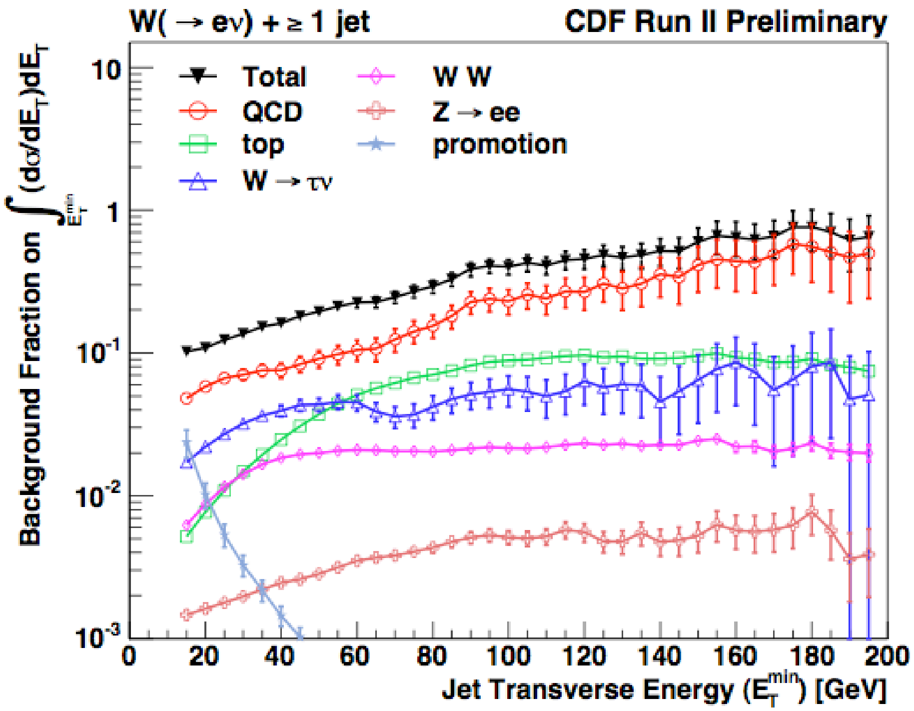


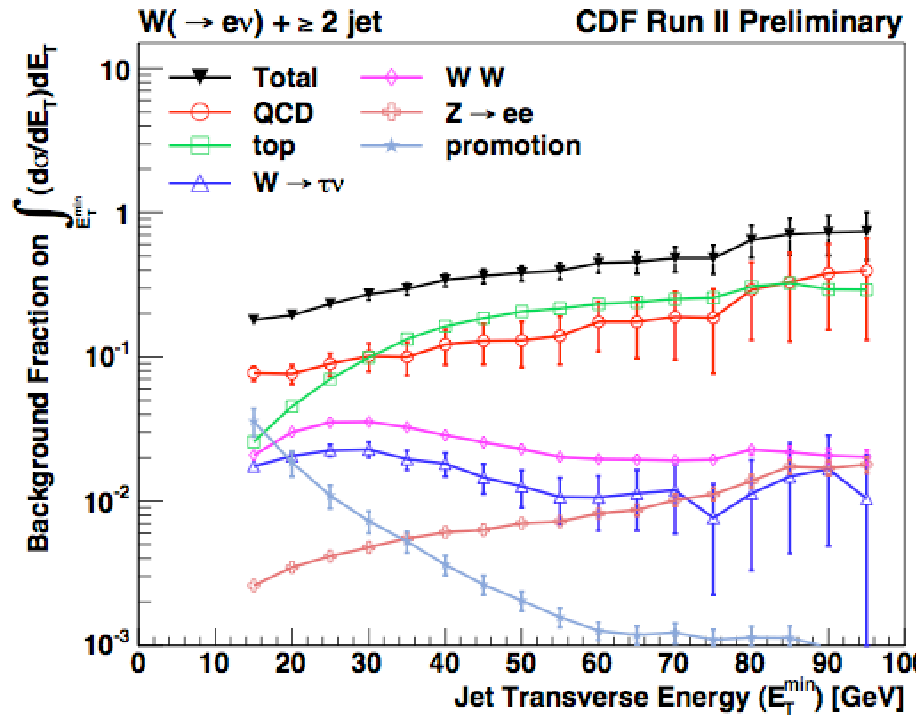
Differential xsec wrt di-jet ΔR in the W+ 2 jet inclusive samples



MC have been normalized to measured W+2 jet inclusive cross section!

Background breakdown in jet E_T





- ✓ QCD gives a substantial contribution to the background fraction
- ✓ In the tail of the distribution (high jet multpl., High E_T) top is dominant

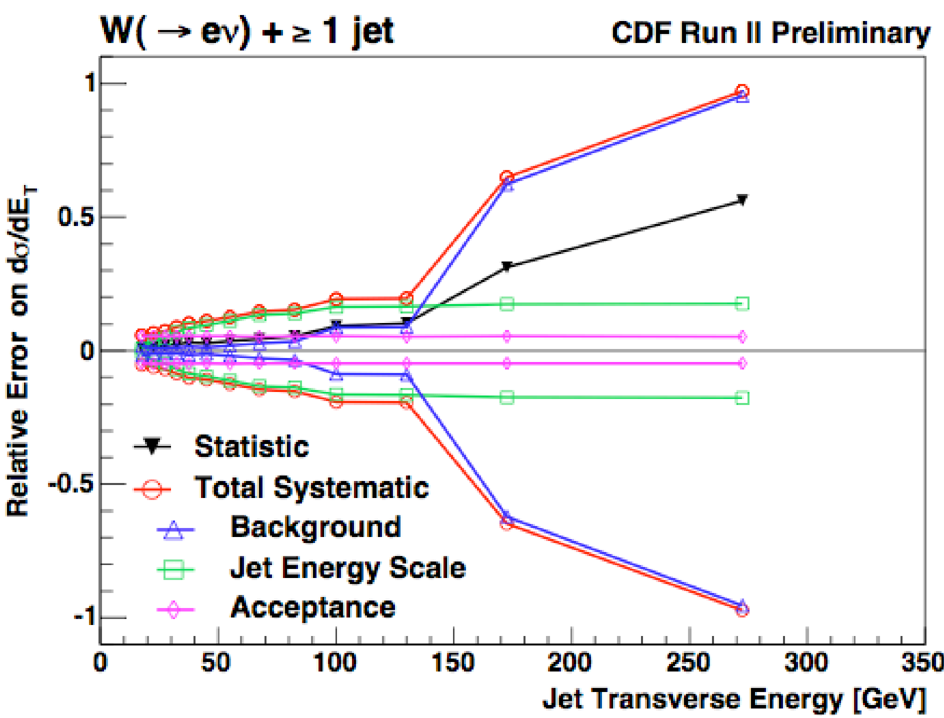
Promotion background (small contribution at low E_T):

- ✓ extra interaction produce jet not associated to the W -> wrong W jet-multipl.
- ✓ Estimate extra jet rate in MB, correct data on average as a function of # vtx

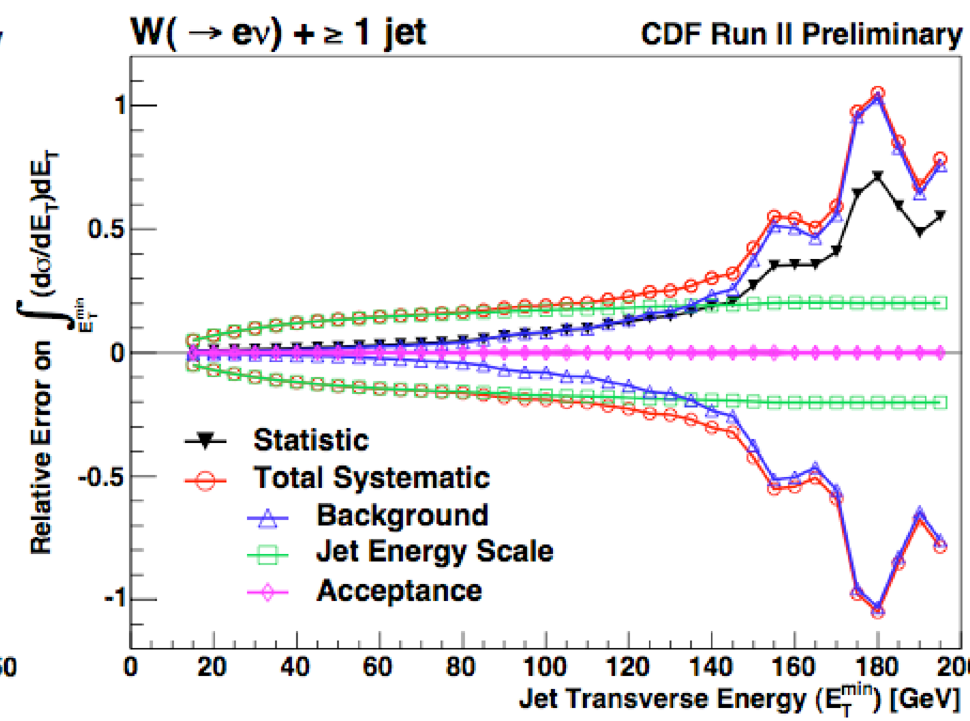
Error breakdown

A representative behavior of the errors in the measurements

Errors on leading jet ds/dE_T



Errors on leading jet Ò$_E$ds/dE_T

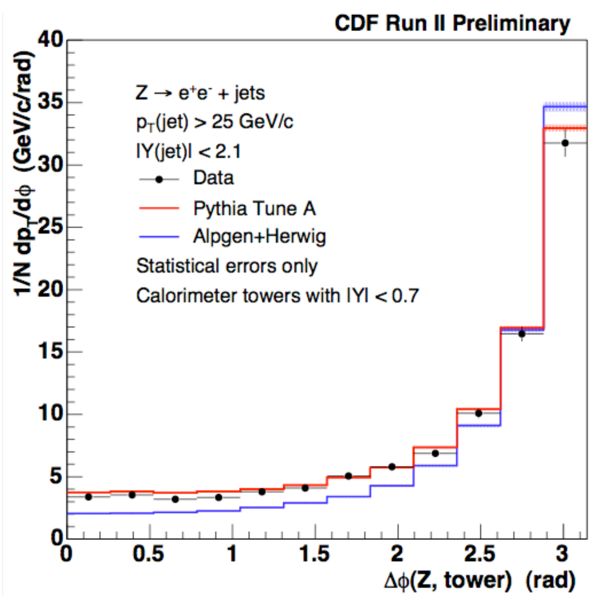


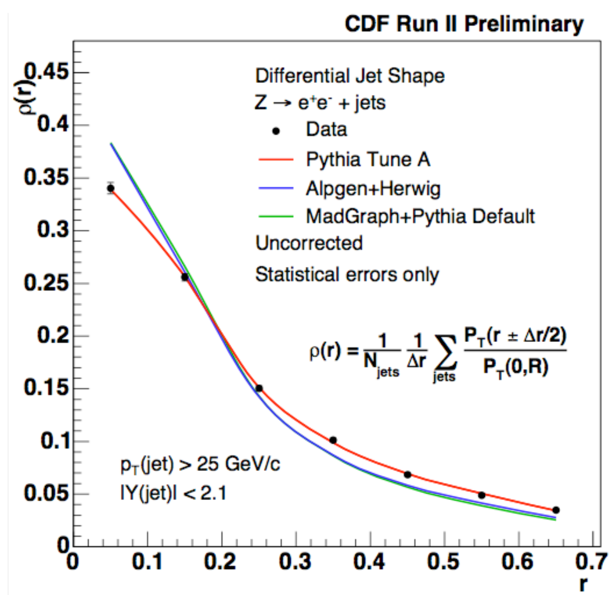
At high E_T large statistic uncertainty. Systematic dominated by jet energy scale(» 3%) at low E_T, by background subtraction at high E_T.

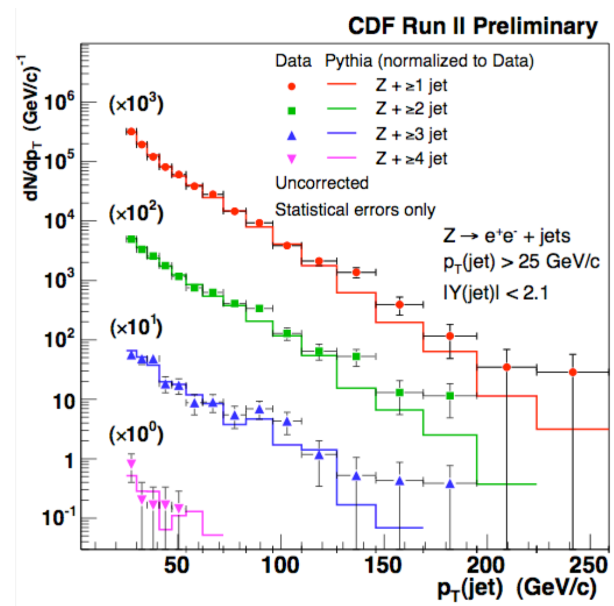
Work in progress and Plans

- ✓ Extend the measurement muons and to $1 fb^{-1}$:
  - Larger E_T range, more sensitive to the tail of the cross section
  - Better control on data driven background subtraction

- ✓ Measure Z+jet cross section and study the underlying event: it is and it will be a crucial issue in the LHC era



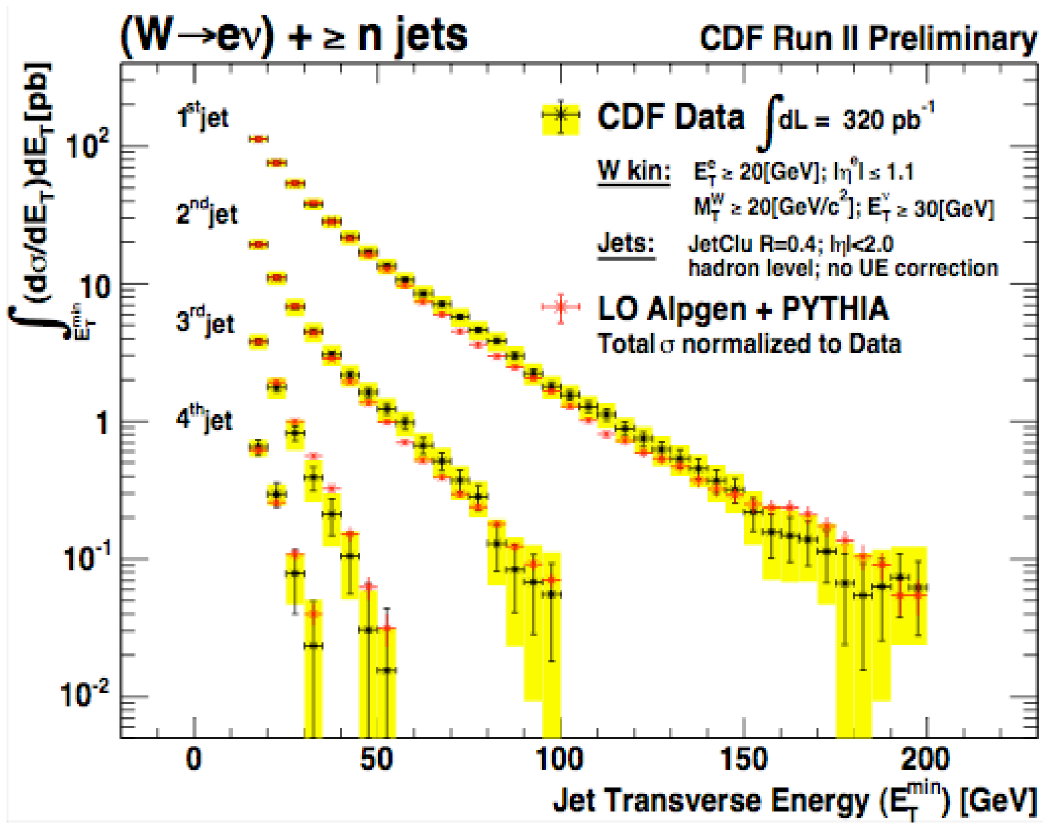




Conclusions

New measurements of s(W+jets) vs jet kinematics with 320pb^{-1}
These measurements more suitable for data/theory comparison:

- Hadron level measurement
- Reduced model dependence on acceptance/efficiency



LO/NLO MC calculation

- Are not exact, may work in different regimes
- parameters need to be tuned on data

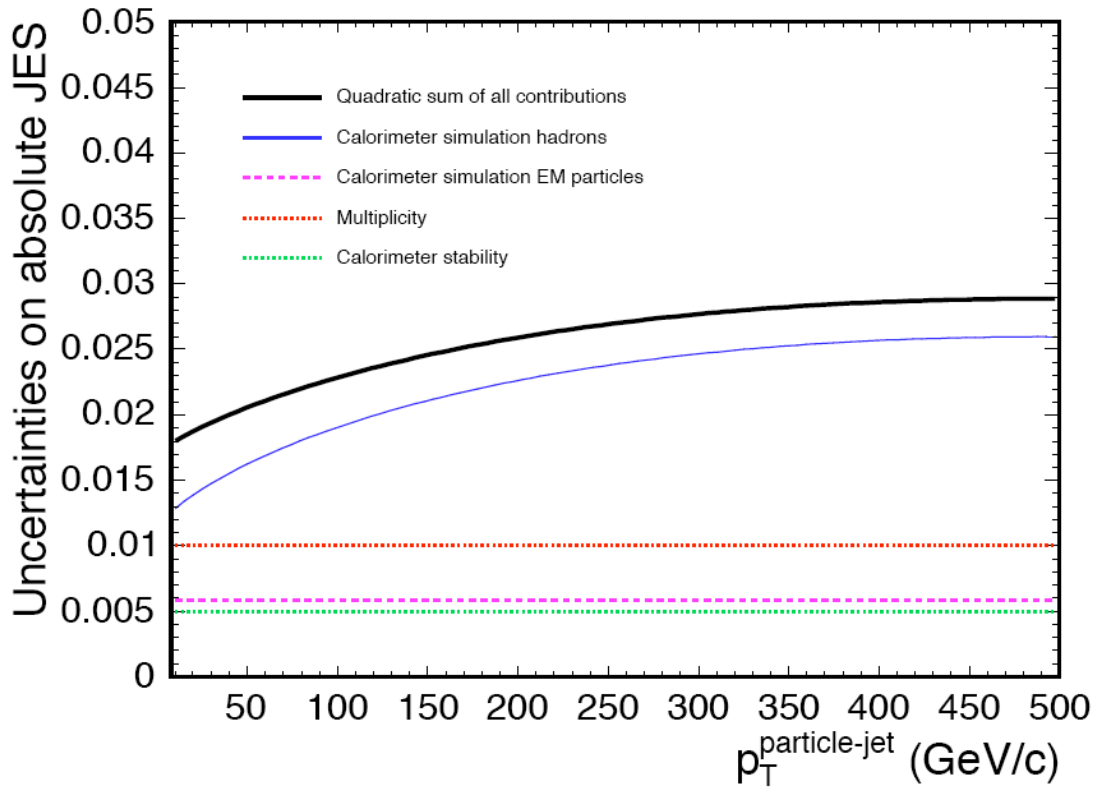
The systematic on many high p_T measurements receives substantial contribution from boson+jet knowledge, crucial to have a robust simulation of boson+jets to explore for new physics at Tevatron & LHC

Jet correction and systematics

Jet definition:
JetClu (cone based)
$E_T^{corr} > 15$GeV $|\eta|<2$

Calorimeter jets, correct:
✓resolution & efficiency
✓pile-up interactions
(<3.6> interactions @ $10^{32}cm^{-2}s^{-1}$)

Hadron jets account for:
✓underlying event
✓fragmentation/hadronization



- Jet corrected to hadron level, systematic < 3%
- Resolution and jet spectrum dependence addressed with additional unfolding on corrected jet E_T distribution